DESIGN
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Anticipating Economizer Failure During Small-Packaged System Installation

Seventy-percent failure rate seen in this study

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Editor's Note: The New Buildings Institute (NBI) is conducting a Public Interest Energy Research (PIER) project for the California Energy Commission (CEC). NBI's project is called Integrated Energy Systems - Productivity and Buildings Science Program. As the name suggests, it is not individual building components, equipment or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction and operation of building systems. One element of the overall project is examining integrated design of small HVAC systems in commercial buildings. The August 2002 article of this series covered design and specification issues that affect HVAC system efficiency. This article will discuss small HVAC system installation issues.

This article summarizes the data from a study of 40 newly constructed commercial buildings throughout California. A total of 140 rooftop units were surveyed; each unit was subjected to a physical inspection, one-time tests of unit power and economizer operation, and short-term monitoring of unit performance. The physical inspections were used to look for obvious problems with the units and gather name-plate data.

Photo A. Short-term monitoring of rooftop unit. Note portable, battery powered data logger in bottom-center of the photo.

Several one-time tests were conducted. First, the units were tested in various operating modes, such as fan only, first-stage cooling, second-stage cooling, etc. The true electric power consumption was measured in each mode using a portable wattmeter.

ECONOMIZERS

If the unit had an airside economizer, the minimum outdoor air position potentiometer was adjusted to test the operation of damper motors and linkages. The economizer outdoor-air temperature sensor was cooled down using a "cool" spray, simulating cool outdoor air conditions and the response of the economizer was observed. Finally each unit was monitored over a 2 to 3 week period using portable, battery-powered data loggers to observe unit operation over a variety of operating conditions (see Photo A).

Diagnostic software was used to analyze the short-term monitored data. Problems were identified based on the results of each test. This analysis identified several installation-related issues that can dramatically affect system performance and efficiency. An example of an economizer diagnostic plot resulting from the short-term monitored data is shown in the sidebar "Economizers in Crisis."

Short-term monitored data from another HVAC unit were plotted in the same format. Units with functioning economizers show a characteristic change in the slope of the line to the left of the vertical (Y) axis, as shown here. The slope in this region is equal to one, indicating a functioning dry-bulb economizer allowing 100-percent outdoor air.

Through a combination of one-time tests and short-term monitoring of economizer systems, the study found that about 70 percent of the economizers tested did not work. What does this have to do with installation practices? According to Dick Lord, Director of Product Engineering at Carrier Corporation and a technical advisor to the project, about 18 percent of rooftop units leave the factory with an economizer, while 68 percent of the units in the field have economizers.

This means that about 70 percent of the economizers in commercial buildings are installed in the field or at the distributor. The high failure rates of economizers observed in this project can be attributed to installation practices that contribute to mechanical and electrical failure of the units, such as stuck or misaligned damper blades, loose linkages, and improper wiring.

Photo B. Ductwork running across the roof, and ductwork located in an unconditioned plenum should be sealed and insulated to prevent energy loss.

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DISTRIBUTION SYSTEMS

Leaky ductwork is a common installation problem plaguing small commercial systems. Ducts in small commercial buildings are often installed in a plenum space between the roof and a suspended ceiling. Insulation is often installed on the ceiling tiles, placing the duct work outside the thermal envelope of the building or above the roof surface. (See photo B.) A recent study of 350 small commercial HVAC systems in Southern California[1] found that 85 percent of the systems tested had excessive duct leakage.

The average combined supply and return leakage in these systems exceeded 35 percent of the total air volume, causing energy waste and poor thermal comfort. Cooling energy savings from sealing duct systems approaches 20 percent when duct systems are located outside the conditioned space. Peak cooling loads are reduced even more when ducts are sealed since attic air that is very warm under these conditions. Our study found that duct leakage sealing can be beneficial even when the insulation is installed at the roof deck, improving the overall efficiency of the HVAC system by 5 percent.

Poor ductwork installation practices can lead to inadequate HVAC unit airflow and excessive fan power. In tests of airflow in small commercial systems, airflow rates averaged about 300 cfm per ton, rather than the nominal 400 cfm per ton used in system-efficiency ratings. Reduced airflow can contribute to coil icing, comfort problems, and a reduction in overall system efficiencies by 10 percent.

Although measured unit air flow rates are generally lower than industry standards, the fan power is higher. Measured fan power in this study averaged around 0.5 w per cfm, which is about 50 percent higher than the nominal 0.375 w per cfm used to compute system efficiency. Fan power can approach 40 percent of the annual HVAC electricity consumption in small systems located in mild climates. Installation problems resulting in higher fan energy include excessive use of flex duct and poor attention to elbows, transitions and unit entry and exit details.

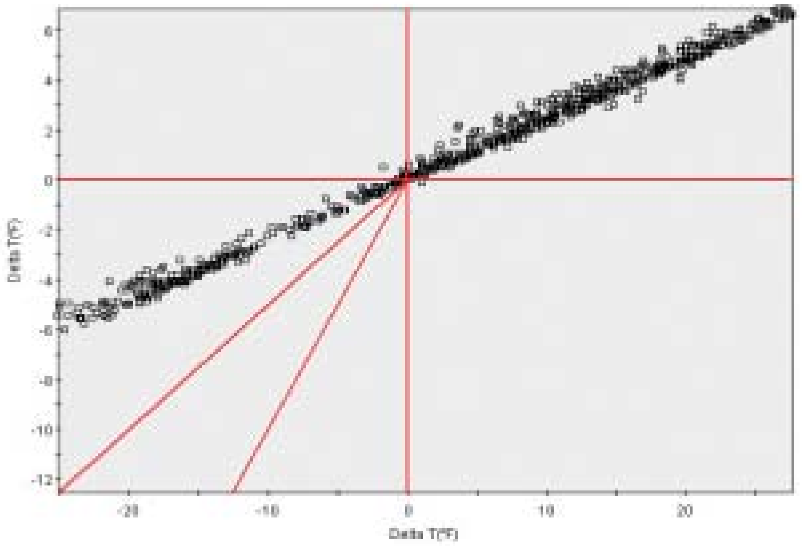
THERMOSTAT CHOICE AND LOCATION

The final installation issue addressed by the project was thermostat installa-

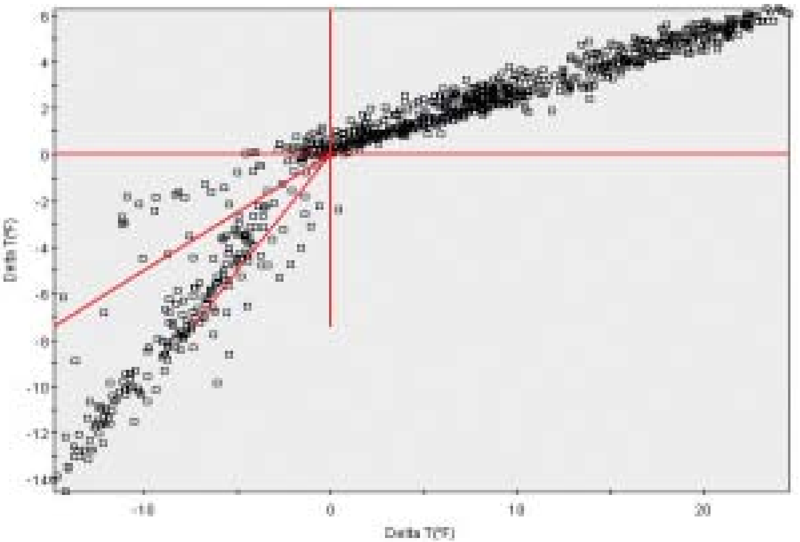
Economizers In Crisis

The top figure shows the economizer plot for an inoperable economizer, while the bottom figure shows the plot for a functioning economizer. The diagnostic software plots short-term monitored data in various formats to help diagnose system problems. The difference between the cooling-coil entering (i.e., mixed) air temperature and the return-air temperature ($T_{mixed} – T_{return}$) on the vertical (y) axis is plotted against the difference between the outdoor (ambient) temperature and the return-air temperature on the horizontal (x) axis ($T_{ambient}$-T_{return}). The slope of the line is equal to the outdoor air fraction. Units with fixed outdoor air (either no or inoperable economizer) have a straight-line relationship between these data. The line in the lower left quadrant closest to the y axis represents an economizer operating properly at 100-percent outside air. The other line represents 50-percent outside air and is included for reference only.

Unit 1: T_{mixed}-T_{return} vs. $T_{ambient}$-T_{return}



Unit 2: T_{mixed}-T_{return} vs. $T_{ambient}$-T_{return}



tion. Location of the thermostat can dramatically affect system loads and occupant comfort. Since the system responds to the air temperature at the thermostat, proper location is key to comfort and energy efficiency. Locating several thermostats in the same general area with conflicting heating and cooling setpoints can invite problems with simultaneous heating and cooling, where adjacent units "fight" each other to maintain selected setpoints (see photo C).

Commercial (not residential) thermostats should be used to provide continuous fan operation and ventilation during occupancy. They will also control the off-hour ventilation cycle and allow daily scheduling of fan operation. Continuous fan operation is critical for ensuring that adequate outdoor air is provided to mechanically ventilated spaces. Intermittent fan operation can reduce the effective ventilation rate of a space by a factor of three.

Continuous fan operation also reduces stuffiness and localized temperature variations that are among the most common complaints in buildings served by small rooftop units. Making sure the thermostats are programmed properly, secured from casual program changes, and have user-friendly controls will help ensure proper operation that is energy efficient comfortable, and meets applicable ventilation standards.

Photo C. Thermostats controlling three different units serving three different computer labs at a community college are located in the corridor, where they are unable to effectively sense the temperature of the rooms they are controlling.

SUMMARY

Installation related problems can confound the best system and equipment designs. For maximum efficiency and comfort, it is important for contractors to pay attention to proper installation and setup; duct selection, craftsmanship, and sealing; and thermostat location.

REFERENCES

1) Modera, M. and J. Proctor (2002, July). "Combining Duct Sealing and Refrigerant Charge Testing to Reduce Peak Electricity Demand in Southern California," Final Project Report for Southern California Edison.

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